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Self-report compared to electronic medical record across eight adult vaccines: Do results vary by demographic factors?

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Abstract

Immunizations are crucial to the prevention of disease, thus, having an accurate measure of vaccination status for a population is an important guide in targeting prevention efforts. In order to comprehensively assess the validity of self-reported adult vaccination status for the eight most common adult vaccines we conducted a survey of vaccination receipt and compared it to the electronic medical record (EMR), which was used as the criterion standard, in a population of community-dwelling patients in a large healthcare system. In addition, we assessed whether validity varied by demographic factors. The vaccines included: pneumococcal (PPSV), influenza (Flu), tetanus diphtheria (Td), tetanus diphtheria pertussis (Tdap), Human PapillomaVirus (HPV), hepatitis A (HepA), hepatitis B (HepB) and herpes zoster (shingles). Telephone surveys were conducted with 11,760 individuals, ≥ 18, half with documented receipt of vaccination and half without. We measured sensitivity, specificity, positive and negative predictive value, net bias and over- and under-reporting of vaccination. Variation was found across vaccines, however, sensitivity and specificity did not vary substantially by either age or race/ethnicity. Sensitivity ranged between 63% for HepA to over 90% (tetanus, HPV, shingles and Flu). Hispanics were 2.7 times more likely to claim receipt of vaccination compared to whites. For PPSV and Flu those 65+ had low specificity compared to patients of younger ages while those in the youngest age group had lowest specificity for HepA and HepB. In addition to racial/ethnic differences, over-reporting was more frequent in those retired and those with household income less than $75,000. Accurate information for vaccination surveillance is important to estimate progress toward vaccination

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coverage goals and ensure appropriate policy decisions and allocation of resources for public health. It was clear from our findings that EMR and self-report do not always agree. Finding approaches to improve both EMR data capture and patient awareness would be beneficial.

Keywords

Immunization; Vaccination surveillance; Self-report

1. Introduction

Because immunization is crucial to the prevention of disease, having an accurate measure of vaccination status for a population can serve as an important guide in targeting prevention efforts.[1,2] To monitor vaccination status, the United States conducts population-based vaccination coverage surveys, [3,4] however, obtaining accurate assessment is difficult. Most people have attended multiple medical practices, leaving records scattered or incomplete. Time may also result in lapses in memory [5–7]. Several vaccinations, such as tetanus/diphtheria (Td), pneumococcal polysaccharide vaccine (PPSV), hepatitis A (HepA) and hepatitis B (HepB) series, may have been administered years before a survey is conducted [6]. Also, patients may affirm receipt of vaccines they believe they should have obtained or deny obtaining a vaccination that might indicate risky behavior [8,9]. Lack of accurate data decreases the ability to interpret estimated coverage levels and may cause providers to miss opportunities to provide needed vaccines. Validity of self-report has been extensively studied for Influenza (Flu) and PPSV [9–15], but there is a paucity of literature on other vaccines (e.g., HepA, HepB) and relatively new vaccines such as Human Papillomavirus (HPV). Further, information on validity that is age and race/ethnicity specific has also had limited study [5,7,16]. In order to comprehensively assess the validity of self-reported adult vaccination status for the eight most common adult vaccines, we conducted a survey of vaccination receipt and compared it to the electronic medical record (EMR) in a population of community-dwelling patients in a large healthcare system. In addition, we assessed whether validity varied by demographic factors. The purpose of this paper is to report the concordance of data obtained through both methods of data collection.

2. Methods

2.1. Study setting and population

This study was conducted in an integrated health care delivery system with 21 primary care clinics, 30 specialty clinics and over 700 practicing physicians. The plan insures over one million people in an open-access system, allowing patients to obtain care within the medical group or the larger network. The vast majority of care is obtained within the network as nearly all services are covered. The majority of the population is white, employed, with education of high school or beyond. Eligible patients were 18 years or older as of January 1, 2007, and seen in one of the medical clinics during 2007.

Health plan Institutional Review Board (IRB) approval was granted for the conduct of this study.

The study was conducted in two phases. The first, was a retrospective review of the EMR data to determine documented receipt of vaccine. In the second phase, a telephone survey was conducted. Concordance of vaccination status between the EMR and self-report from survey results was assessed.

In Phase 1, EMR data were examined for patients seen in 2007. For HepA this timeframe was expanded back to 2001 to ensure adequate numbers of potential subjects. All vaccination information was obtained for each patient as far back as it was available. The denominator of those eligible for each vaccine was determined and a vaccine specific database was created. The eight vaccines studied included: PPSV, Flu, tetanus/diphtheria Td), tetanus/diphtheria/acellular pertussis: (Tdap), HPV, HepA, HepB and herpes zoster vaccine (shingles). Data were stratified by age group for most vaccines and by race/ethnicity for PPV and Flu.

Vaccination history was retrieved from information obtained from patients when they entered the health system, which was entered into the EMR as were vaccinations obtained within the system. A vaccination procedure code as well as the facility where it was obtained, lot number and vaccine manufacturer were considered evidence of vaccination. For each vaccine, the date of the most recent vaccination was recorded ensure we were using the most relevant information.

EMR data were sorted by vaccine and within each vaccine for the ages and racial/ethnic specific groups of interest to the Centers for Disease Control and Prevention (CDC). For surveys of PPSV, tetanus, HepA, and Flu vaccination, the age groups sampled were for 18–49 years, 50–64 and 65+; for shingles (50–64 and 65+); HepB (18–49 and 50–64) and HPV (females 18–26). Specific racial/ethnic groups (White, Black, Hispanic) were targeted for those 65+ for the PPSV vaccine and all three age categories for Flu. For each group we determined the underlying EMR vaccination rate. We then sorted based on documented evidence of receipt of vaccination: those with and without. After creating all age and race/ethnicity groups by receipt or no receipt of vaccine, there were a total of 56 sampling strata (Appendix A).

2.2. Patient survey

For Phase 2, the patient survey, we randomly selected 300 individuals from each strata, to ensure 200 completed surveys. Two weeks prior to initiating the telephone calls for a given strata, the EMR data was refreshed to be certain all vaccination information was current. Anyone with modified information was reclassified. Letters of invitation for participation were then sent to the 300 randomly selected individuals. There were up to 15 attempts to reach each patient by telephone. Surveys were conducted between January 2009 and March 2011. The intention was to ask any individual about just one vaccine. However, in order to fill some strata (i.e. Hispanic 65+, Black 65+) 339 subjects were surveyed for more than one vaccine.

2.3. Survey content

Surveys were created for each vaccine. Subjects were asked if they “ever” received the vaccine in question. Responses were “yes”, “no”, “don’t know”, and “refused to answer.”

Follow-up questions varied by vaccine regarding how long ago the immunization was obtained. Subjects surveyed about tetanus vaccination were also asked if they were told if the vaccine contained pertussis (whooping cough). Specifics on all vaccines can be found in Table 2. The core content of all surveys was similar. Demographics included: age, sex, race/ethnicity, marital status, education, employment and annual household income. We asked whether reported information was based on recall or if participants had records of vaccination status. Patients with no EMR documentation, claiming to have been vaccinated, were asked if they had any evidence. Some immigrants (<5%) had vaccination history cards.

2.4. Statistical analysis

Demographic characteristics were reported overall and by self-reported vaccination status. In order to assess the validity of self-reported vaccination status, we measured sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). In addition, we assessed net bias and lack of concordance indicated by over-and under-reporting of vaccination.

We calculated agreement statistics sensitivity, specificity, positive predictive value, and negative predictive value.[17] Additionally, we calculated a Kappa statistic,[18] to measure agreement between self-report and EMR (agreement was categorized as follows: almost perfect 0.81–1.00, substantial agreement 0.61–.80, moderate agreement 0.41–0.60, fair 0.21–0.40, and poor <0.21). These validity parameters were calculated for all vaccines and for each vaccine separately. Clinically, if a patient can't affirm that they have had the vaccine, a provider may offer the vaccine, thus we considered the lowest coverage scenario where all "don't knows" for self-reported vaccination status were considered "no".

Biased estimates can occur as a result of unequal sampling rates across strata. To correct for the unequal sampling rates of vaccinated and unvaccinated persons across sampling strata, all study data were weighted to reflect the actual distribution of EMR vaccination status among study-eligibles within each of the age and race/ethnicity-specific strata. Sampling weights were computed as the reciprocal of the achieved sampling fraction for each stratum. The weighted analysis results in numbers that sum to that of the original population. Statistical analyses of validity measures accounted for the complex sampling methods and weighting. All statistical analyses were conducted using SAS version 9.2 (SAS Institute, Inc., Cary, NC).

Net bias was calculated as the estimated vaccination coverage estimate (self-reported vaccination) minus the actual vaccination coverage estimate (EMR based). In order to compare vaccines with varying coverage levels, we also calculated net bias relative difference (estimated vaccination – actual vaccination)/actual vaccination) and multiplied by 100 to get percent. In addition, we calculated proportions under- and over-reporting (1-sensitivity and 1-specificity, respectively).

To test whether over- or under-reporting differed by patient characteristics (self-reported race/ethnicity, sex, age, marital status, employment status, education status, and income level) we conducted a series of logistic regression models using the entire survey sample for all eight vaccines to estimate odds ratios and 95% confidence intervals. For under-reporting,

we restricted the analysis to those who had EMR documentation of vaccination and modeled the likelihood of self-report of no vaccination as a function of patient characteristics one at a time. Because 339 subjects (<3%) were surveyed for two vaccines and all others were surveyed for only vaccine, we conducted a sensitivity analysis to see if the assumption of independence was violated. The logistic regression models examining over- and under-reporting were run excluding the second observation recorded for each subject with more than one survey.

2.5. Additional follow up

To further assess the completeness of our data, we conducted a substudy. There were two groups where misclassification would be most likely to exist: those reporting having had the vaccination where we had no EMR record (the more obvious group) and those who had neither an EMR record nor self-report of vaccination. In the first group, we asked for any evidence of receipt of vaccination and if evidence was available, the patient was reclassified. For the latter group, we inquired if they might have any additional medical history elsewhere. We then asked for consent to allow us to check medical records outside our health care system. Resources were available to conduct this additional check for unrecorded vaccination on 330 patients. We were able to identify and follow up on 279 (85%) who met the required eligibility (no record in EMR, self-report of no vaccination, attended a clinic outside of those within the health system and gave permission to contact the outside clinic).

3. Results

The goal of 11,200 completed surveys was based on 200 each from the 56 strata. We ended with 11,760 completed surveys: 10,670 toward goal and 1090 over. The overage occurred due to an initial flaw in the tracking program affecting all HepA (overage = 713). Overage was also due to multiple interviewers continuing to survey until informed that the goal was achieved. For non-Hispanic blacks 65+ and Hispanics with no evidence of PPSV or Flu vaccination, numbers in the base population were insufficient to achieve our goal. Thus, although our intention was to survey each individual about only one vaccine, for certain strata we used an individual more than once. There were 339 (<3%) individuals who were surveyed about more than one vaccine. Over half of these were Hispanic.

Table 1 presents the demographic characteristics of the study sample. Because certain ages and race/ethnicities were dictated by the study, the balance is as expected. The fields dictated by the study protocol are shaded. The other variables are reflective of the health plan’s population.

3.1. Agreement statistics

The sensitivity of self-reported vaccination status for true vaccination status, based on EMR data, ranged between 63% (HepA) and over 90% (Td, Tdap, HPV, shingles and Flu). Specificity varied widely from 11% for Tdap and Td to 91% for PPSV. PPV varied from below 50% for Shingles, HepA and HepB to 80% for HPV. NPV was over 90% for all vaccines except tetanus (55%). When asked if their tetanus shot included the pertussis vaccine, 10% of those who claimed to receive tetanus vaccine said they received the

pertussis vaccine, 11% said no, 17% said the provider did not say, and the remaining 61% did not know.

EMR vaccine coverage based on the source population is shown in Table 2. Table 2 also presents net bias and net bias relative difference. Net bias estimates ranged from −0.8 to 39.0 for PPSV and tetanus, respectively. Values for net bias relative difference ranged considerably across vaccines; from low (PPSV and HPV) to moderate (HepA, Flu) to high (tetanus, shingles and HepB).

Table 3 reports the agreement per vaccine for race/ethnicity and age strata. With the exception of PPSV, sensitivity did not vary considerably by age and/or race/ethnicity within vaccine strata. With regard to specificity, for PPSV, and Flu, those over 65 had low specificity compared to patients of younger ages. In contrast for HepA and HepB, those in the youngest group had the lowest specificity. Low specificity was also found with Hispanics for Flu vaccine. With some exceptions, NPV generally was high; however, for PPSV those over 65 had low NPV as did tetanus for all ages. PPV varied by age for PPSV, with those 65+ with the highest values and for shingles, those 50–64 were highest.

In order to examine differences in over- and under-reporting as a function of patient characteristics combined across all vaccines, we conducted logistic regression adjusted for age and sex (Table 4). Compared with those ages 18–49, those 50–64 had a slightly lower odds of under-reporting. Black subjects and those reporting other race/ethnicity had 3-fold higher odds of over-reporting, but no association was observed with under-reporting. Hispanic subjects had a 4-fold greater odds of over-reporting and had 60% lower odds of under-reporting compared with whites. Retired subjects had higher odds of over-reporting and lower odds of under-reporting compared to those working/homemaker/or student. Those with household incomes below $75,000 were more likely to over-report and less likely to under report compared with those making $75,000 or more. Compared with those who reported some college, those with a high school diploma or less were 2.3-fold more likely to over-report. We did not observe strong associations of over- or under-reporting by marital status.

In addition, we conducted a sensitivity analysis to see if over-or under-reporting differed when we excluded the second observation for the subjects who were surveyed for more than one vaccine. For this series of analyses, the odds ratios for each demographic characteristic were similar except for gender, where in the sensitivity analysis for over-reporting males had higher odds of over-reporting compared to females.

3.1.1. Additional follow up patients—For the 279 patients who had no record in EMR of vaccination, self-report of no vaccination, attended a clinic outside the system and gave permission to contact the outside clinic, we were able to obtain information on 246 (88%). Of the 246 total patients with information obtained outside of our system, 8 were found to have received vaccinations (3%). Three of the 8 vaccinations were for PPSV, two for shingles and one each for Tdap, Td and HPV.

3.2. Sensitivity analyses

While we report the results of the lowest coverage scenario by counting “don’t know” responses as “no”, we conducted additional sensitivity analyses (data not shown). We compared the effects on validity measures when all “don’t know” responses were considered “yes” and found sensitivity improved slightly and specificity measures decreased slightly for all vaccines except Flu, for which measures of sensitivity and specificity were virtually the same.

4. Discussion

The purpose of this study was to examine self-reported vaccination status compared to EMR data. Considerable variation was found by vaccine, age and race/ethnicity. We also assessed rates of under-and over-reporting and net bias. Under-reporting was relatively low, except in the Hispanic strata, while over-reporting varied by vaccine. The net bias relative difference also varied widely. We found more favorable agreement statistics for PPSV and HPV. Tetanus had the largest net bias relative difference.

Findings on sensitivity, specificity, PPV and NPV, were consistent with the literature [9–15]. Flu studies have reported higher sensitivity with lower specificity [9–11,13]. In a recent study, however, examining the accuracy of Flu vaccination from four Vaccine Safety Datalink sites, sensitivity ranged from 0.51–0.89, highest in those ages 65–79 and those at high risk [8]. While our findings for those age 65+ were also highest (96% versus 89% for age 18–49), specificity was the lowest of all age groups (50% versus 68% for those 18–49). Findings for PPSV vaccination have been reported as more variable, perhaps due to more distant recall [14,19].

The self-report accuracy of HepB vaccination has been poorly studied. One study using serological data found self-report to be unreliable [20]. However, others examining self-report of Flu, tetanus booster, and HepB found patient questionnaire nearly as sensitive and specific (hepatitis B: sensitivity 80%, specificity 100%) as the medical record [12]. Our findings were a bit lower for HepB specificity (sensitivity 0.73, specificity 0.67). HepB is administered primarily for employment or as a travel vaccine with a number of other vaccines, and no boosters, so recall may be difficult.

Inaccurate patient reporting has implications for both clinical care and estimates of vaccination coverage [1,2,8,21]. A positive net bias in vaccine coverage level estimates may indicate better progress toward disease control and achievement of national and local health objectives than is true.

Our patients were not asked to distinguish between Td/Tdap so we collapsed them for examination; the reason for the low specificity is unclear. Perhaps the 10-year duration between vaccinations forTd and newness of Tdap is part of the explanation. If a tetanus vaccination was given several years ago it is possible it was administered before the patient entered our healthcare system and they did not report it upon intake into the system.

4.1. Limitations

This study has several potential limitations. First it was conducted in a single health plan so findings may not be representative of other populations. Further, survey participants may differ from non-participants, although we did select a random sample from each strata. For some vaccines, the EMR may not always have gone back as far as needed, leading to some misclassification. In addition, it is possible that patients may have obtained vaccinations outside of the health system, particularly for the Flu vaccination which is commonly available in work and retail settings [22,23]. If patients did not report obtaining these to a provider, they would be missed. Our overall findings for the shingles vaccine should be taken with caution, as we surveyed ages 50 and over and the Adsvisory Committee for Immunization Practices recommendation for obtaining this vaccine starts at age 60 [24]. Thus, because of differences in study population, survey question wording, recall period and other methodological differences, results from this study may not be comparable to self-reported data from other surveys such as the National Health Interview Survey [25].

Despite its limitations, the assessment of the accuracy of self-report using telephone survey for each of the vaccines studied is a major strength of the study. The population was large, with demographic data and robust vaccination histories. This enabled us to examine self-report by age and race/ethnicity. The comprehensive medical record allowed the team to readily identify the underlying populations of interest, obtain documented vaccination data on all and compare self-report to EMR. The presence of vaccination in the EMR provided strong evidence that vaccination had occurred, although lack of documentation did not guarantee that no vaccination had been obtained. Few studies have tested the accuracy of telephone survey self-report for many of the vaccines studied. While Flu and PPSV have had extensive study, limited data exists on the newer shingles or the HPV vaccinations. Our study adds to our understanding of well-reported vaccination coverage as well as reporting on lesser-studied vaccinations.

Accurate information for vaccination surveillance is important to be able to estimate progress toward Healthy People 2020 vaccination coverage objectives and to ensure appropriate policy decisions and allocation of resources for public health. It was clear from our findings that EMR and self-report do not always agree. Finding approaches to improve both EMR data capture and patient awareness would be beneficial. The EMR may not always be accurate if vaccination occurred in the past. It is also possible that vaccines obtained outside the system are not getting captured. With growing number of pharmacies offering vaccinations, health system records may become less trustworthy. According to Sy, if there is no record in data base, there is a 20% chance that vaccination was obtained in a different setting [2]. Assisting patients to improve recall would also be advantageous. Like others, we found higher rates of over-reporting compared to under-reporting [5]. With today’s technology it is possible to have patients record their vaccinations into personal devices and electronic applications. Information from such applications could be part of inquiry at office visits, similar to updating address and telephone number information. The portability of the EMR and immunization registries could also facilitate improved accuracy of vaccination status.

5. Conclusions and future directions

Health system electronic databases provide ready capture of data on vaccinations, yet potential for misclassification cannot be ignored. As more vaccines are available in non-traditional settings, this problem is likely to become more common. We must continue to find ways for both health plans and patients to capture and communicate information on vaccination status to ensure surveillance efforts are as robust as possible.

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Appendix A. Vaccine target groups and eligibility status

Vaccine	Age groups	Race/ethnicity groups	Additional eligibility criteria
Pneumococcal (PPV)	65+	White Black Hispanic	
	50–64	All races	Forages 18–64: patients with risk factors: American Indian or Alaska Native; history of diabetes, lung disease, heart disease, kidney disease, liver disease, anemia spleen (including sickle-cell disease), cancer, immunodeficiency (HIV/AIDS), organ transplant, rheumatologic diseases (treatment involved taking steroids), alcoholism, splenectomy, spinal fluid leak
	18–49		
Influenza (LAIV/TIV)	65+ 50–64 18–49	White Black Hispanic	
Tetanus (Td) Tetanus (Tdap)	65+ 50–64 18–49	All races	
HPV	18–26	All races	Females only
Hepatitis A	65+		In addition to those seen in 2007, we included those who had a diagnosis of liver disease or Hemophilia or took a Hepatitis A laboratory test at one of owned clinics during 2001–2007.
	50–64	All races	
	18–49		
Hepatitis B	50–64	All races	Patients with risk factors which include: Asian or Pacific Islander ethnicity, history of a sexually-transmitted disease, kidney disease, liver disease, hemophilia, Immunodeficiency (including HIV/AIDS).
	18–49		
Shingles	65+ 50–64	All races	

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Table 1

Demographic characteristics of study sample.

	Overall	PPV	Tetanus	HPV	Shingles	HepA	HepB	Flu
N	11,760	1939	2549	405	846	1704	818	3499
Male (%)	38	37	41	–	40	41	40	40
Age (%)								
18–49	33	21[a]	34[a]	100[a]		33[a]	49[a]	36[a]
50–65	34	21[a]	34[a]	–	50[a]	32[a]	51[a]	37[a]
65+	33	58[a]	32[a]		50[a]	35[a]	–	27[a]
Race/ethnicity								
Non-Hispanic white	68	59[a]	87	77	95	85	83	37[a]
Non-Hispanic black	15	20[a]	6	5	2	6	8	30[a]
Hispanic	11	16[a]	0	0	0	0	0	29[a]
Other	16	4[a]	8	13	3	9	9	4[a]
Educational attainment								
HS grad or less	27	38	23	15	21	21	17	33
Some college or college grad	52	44	56	75	50	52	58	49
More than college	20	17	21	10	29	27	24	16
No data	1	<1	<1	<1	<1	<1	<1	2
Employment status								
Working/homemaker/student	57	44	62	92	29	53	72	61
Unable to work, can’t find work	9	9	7	7	4	10	14	11
Retired	33	46	30	0	67	37	15	27
No work data	<1	<1	<1	<1	<1	<1	<1	1
Marital status								
Married/couple	58	53	63	29	65	61	63	57
No longer married	25	34	22	1	30	25	15	26
Single	16	12	14	70	5	13	21	16
No data	1	<1	1	0	<1	<1	<1	2
Household income								

	Overall	PPV	Tetanus	HPV	Shingles	HepA	HepB	Flu
<$75,000	53	58	47	62	53	51	48	56
≥$75000	25	19	30	15	22	31	35	22
No data	22	23	23	24	25	19	17	22

[a]Indicates targeted sampling with regard to strata.

Table 2

Agreement statistics and 95% confidence intervals for 7 common vaccines[a].

	PPV	Tetanus	HPV	Shingles	HepA	HepB	Flu
Source population (*N*)	195,792	233,113	22,466	98,719	15,804	40,042	200,818
Coverage in source population[b] (%)	28.6	56.9	55.7	9.3	15.7	27.7	41.7
Survey population, n	1939	2549	405	846	1704	818	3499
Self-reported vaccination[c] (%)	27.8	95.9	57.9	17.8	23.3	44.3	60.6
Kappa	0.65 (0.63–0.67)	0.03 (0.03–0.04)	0.67 (0.63–0.72)	0.57 (0.54–0.60)	0.39(0.37–0.41)	0.33 (0.30–0.36)	0.56 (0.54–0.57)
Sensitivity[d]	73.8 (70.3–77.2)	92.1 (90.4–93.8)	91.2(87.3–95.1)	90.7 (87.8–93.5)	62.5 (59.0–66.0)	72.6 (67.6–77.6)	93.0(91.3–94.8)
Specificity[d]	90.7 (88.4–93.0)	11.0(9.0–13.0)	76.1 (70.2–82.1)	89.7 (86.7–92.6)	84.0(81.6–86.4)	66.6(62.0–71.1)	65.7 (61.9–69.5)
Positive predictive value[d]	76.0 (76.0–76.0)	57.7(57.7–57.7)	79.6 (79.6–79.6)	47.4 (47.4–47.4)	42.1 (42.1–42.1)	45.5 (45.5–45.5)	66.0 (66.0–66.0)
Negative predictive value[d]	90.9 (90.9–90.9)	55.0(55.0–55.0)	92.5 (92.5–92.5)	99.1 (99.1–99.1)	94.0(94.0–94.0)	90.6 (90.6–90.6)	93.1 (93.1–93.1)
Net bias estimate	−0.8	39	2.2	8.5	7.6	16.6	18.9
Net bias relative (%)	−2.9%	68.5%	3.9%	47.8%	48.4%	59.9%	45.3%

[a]For each vaccine, we asked if the participant knew which year he/she had received the last vaccination. Where exact year was not known, we prompted participants asking roughly how long ago they received the vaccination. Prompts varied by vaccine. For HepA and HepB, prompts were: 12 months, last 5 years, last 10 years, more than 10 years ago. For PPV and tetanus, prompts were: last 12 months, last 2–5 years, last 6–10 years, more than 10 years ago. For flu, we asked not only if they received the vaccination during the past year but if they could give the month they received the flu vaccination and for shingles and HPV we asked only the year of vaccination.

[b]Coverage based on EMR evidence in source population.

[c]Based on survey results.

[d]Reported as percentage.

Table 3

Agreement statistics and 95% confidence intervals by targeted strata (reported as percentage).

Vaccine	*n*	Kappa	95% confidence interval	Sensitivity[a]	95% confidence interval	Specificity[a]	95% confidence interval	PPV[a]	95% confidence interval	NPV[a]	95% confidence interval
PPV											
Race/ethnicity											
Non-Hispanic white	1155	0.67	0.65–0.70	76.3	72.6–80.0	90.7	88.3–93.1	77.4	77.4–77.4	91.7	91.7–91.7
Non-Hispanic black	431	0.43	0.38–0.48	56.9	46.0–67.9	85.3	70.8–99.9	60.6	60.6–60.6	84.4	84.4–84.4
Hispanic	315	0.53	0.47–0.58	46.5	28.5–64.5	97.8	97.5–98.0	85.9	85.9–85.9	88.2	88.2–88.2
Age											
18–49	404	0.59	0.54–0.64	63.2	56.5–69.9	96.1	93.4–98.8	62.8	62.8–62.8	96.4	96.4–96.4
50–65	413	0.55	0.51–0.60	72.0	65.8–78.1	84.5	79.5–89.5	67.6	67.6–67.6	89.4	89.4–89.4
65+	1122	0.24	0.21–0.26	78.6	73.4–83.6	48.9	42.7–55.1	87.1	87.1–87.1	38.8	38.8–38.8
Tetanus											
Age											
18–49	439	0.04	0.02–0.05	91.8	89.2–94.4	11.4	8.4–14.4	57.2	57.2–57.2	47.3	47.3–47.3
50–65	406	0.02	0.01–0.03	93.2	90.7–95.7	8.5	5.8–11.1	62.8	62.8–62.8	58.8	58.8–58.8
65+	404	0.04	0.03–0.05	91.1	87.8–94.5	12.8	8.8–16.7	50.0	50.0–50.0	70.3	70.3–70.3
Shingles											
Age											
50–65	419	0.49	0.44–0.54	88.7	84.3–93.1	90.7	86.8–94.6	79.6	79.6–79.6	99.3	99.3–99.3
65+	427	0.64	0.59–0.68	92.1	88.3–95.8	87.6	83.2–91.9	57.0	57.0–57.0	98.5	98.5–98.5
HepA											
Age											
18–49	555	0.35	0.31–0.39	67.7	61.9–73.6	78.2	73.5–82.8	38.4	38.4–38.4	92.2	92.2–92.2
50–65	456	0.43	0.39–0.47	65.2	59.4–71.1	83.8	79.5–88.1	47.9	47.9–47.9	94.3	94.3–94.3
65+	603	0.34	0.30–0.38	46.5	40.6–52.3	90.9	87.7–94.1	37.9	37.9–37.9	94.8	94.8–94.8
HepB											
Age											
18–49	400	0.26	0.22–0.30	70.0	63.6–76.4	58.5	51.6–65.4	49.1	49.1–49.1	82.3	82.3–82.3
50–65	418	0.38	0.34–0.43	80.8	75.5–86.2	75.0	69.0–81.0	37.9	37.9–37.9	96.1	96.1–96.1
Flu											

Vaccine	*n*	Kappa	95% confidence interval	Sensitivity[a]	95% confidence interval	Specificity[a]	95% confidence interval	PPV[a]	95% confidence interval	NPV[a]	95% confidence interval
Race/ethnicity											
Non-Hispanic white	1376	0.57	0.54–0.59	94.0	92.1–96.0	65.1	60.7–69.6	67.4	67.4–67.4	93.7	93.7–93.7
Non-Hispanic black	1089	0.54	0.51–0.57	82.7	79.2–86.3	72.1	67.2–77.0	58.7	58.7–58.7	89.8	89.8–89.8
Hispanic	1000	0.38	0.35–0.41	89.8	87.2–92.4	55.4	51.1–59.6	50.4	50.4–50.4	91.7	91.7–91.7
Age											
18–49	1246	0.52	0.50–0.55	90.1	86.9–93.4	68.1	62.7–73.4	57.2	57.2–57.2	93.9	93.9–93.9
50–65	1308	0.62	0.59–0.65	94.8	92.3–97.3	66.8	61.2–72.4	74.7	74.7–74.7	92.5	92.5–92.5
65+	945	0.49	0.45–0.52	95.8	93.2–98.4	49.5	43.1–56.0	72.9	72.9–72.9	89.3	89.3–89.3

[a]Reported as percentage.

Table 4

Odds ratios and 95% confidence intervals in the relationship of patient characteristics with over-reporting and under-reporting.

	Over-reporting[a,c] *N* = 6074	Under-reporting[b,c] *n*=5686
Gender		
Female	1.0 REF	1.00 REF
Male	1.56 (1.22–2.01)	1.16 (0.99–1.36)
Age(%)		
18–49	1.00 REF	1.00 REF
50–64	0.85 (0.64–1.14)	0.61 (0.54–0.70)
65+	1.10 (0.83–1.47)	1.13 (0.99–1.30)
Race/ethnicity		
Non-Hispanic white	1.00 REF	1.00 REF
Non-Hispanic black	3.37 (2.26–5.01)	0.92 (0.70–1.21)
Hispanic	4.00 (2.53–6.32)	0.40 (0.21–0.74)
Other	2.90 (1.80–14.69)	1.67 (1.21–2.30)
Educational attainment		
HS grad or less	2.28 (1.68–3.09)	0.92 (0.76–1.12)
Some college or college grad	1.0 REF	1.00 REF
More than college	0.83 (0.60–1.15)	0.98 (0.80–1.20)
No data	1.61 (0.32–8.19)	2.17 (0.88–5.40)
Employment status		
Working/homemaker/student	1.00 REF	1.00 REF
Unable to work, can’t find work	2.10 (1.39–3.19)	1.04 (0.78–1.38)
Retired	1.17 (0.78–1.75)	0.65 (0.51–0.82)
No work data	0.68 (0.12–3.91)	2.23 (0.75–6.59)
Marital status		
Married/couple	1.0 REF	1.00 REF
No longer married	1.40 (1.00–1.94)	0.71 (0.48–1.06)
Single	1.42 (0.99–2.04)	0.73 (0.47–1.14)
No data	1.93 (0.56–6.64)	0.44 (0.11–1.72)
Household income		
<$75,000	1.74 (1.28–2.38)	0.80 (0.66–0.96)
≥$75,000	1.00 REF	1.00 REF
No data	2.09 (1.44–3.01)	0.85 (0.68–1.07)

[a] Models restricted to those with EMR documentation of vaccination.

[b] Models restricted to those with no EMR documentation of vaccination.

[c] All models adjusted for sex and age.